High Frequency Propagation and Scattering in Coastal Waters

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LONG-TERM GOALS

To develop a firm physical and oceanographic basis for modeling propagation relevant to acoustical communications in the presence of bubbles. We identify the link between the acoustic modeling and the modeling of the hydrodynamics and bubble distribution as a key to a robust, physics based understanding of propagation in these environments. Our goal is to acquire appropriate measurements and use the data sets to test appropriate propagation models.

OBJECTIVES

Our objectives are (1) to establish the link between surface gravity waves and their associated breaking, subsurface bubble distribution and the ambient noise field; (2) implement a hydrodynamic model of bubble movement and evolution and test this model against observations of wavefield and whitecap distribution, bubble injection, turbulence, dissolution and Langmuir circulation; (3) propagate high frequency sound through this turbulent, bubbly region; and (4) combine the hydrodynamic bubble model with an acoustic scattering and propagation model.

APPROACH

The chosen approach has involved the use of high frequency propagation systems in different environments relevant to acoustic communications. These include the surf zone and surf generated rip currents, in higher wind state conditions in shallow and deep waters where breaking waves are the main source of bubble clouds. We are presently preparing for a major experiment at Martha's Vineyard planned for October and November 2002, where experience and insight from earlier studies of acoustic propagation in coastal water with significant bubble populations is being utilized in the experimental design. As part of this effort we are also developing acoustic propagation and scattering models applicable to these environments in which the acoustic models are directly coupled to time evolving hydrodynamic models of the bubble distribution. For propagation in the surf zone our analysis includes scattering from bubbles in a wedge shaped environment. Propagation in bubble clouds advected by currents in shallow water is modeled using a bubble size distribution that evolves under the combined influence of bottom-generated turbulence, buoyancy effects and bubble dissolution. Our

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14. ABSTRACT

To develop a firm physical and oceanographic basis for modeling propagation relevant to acoustical communications in the presence of bubbles. We identify the link between the acoustic modeling and the modeling of the hydrodynamics and bubble distribution as a key to a robust, physics based understanding of propagation in these environments. Our goal is to acquire appropriate measurements and use the data sets to test appropriate propagation models.

15. SUBJECT TERMS

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approach to high frequency propagation near the ocean surface in the presence of bubbles includes observational and model analysis of the relative contribution of specular and volume scatter.

As part of our continuing development of bubble measurement capability we are rebuilding our acoustical resonator instruments and are carrying out acoustical reverberation analysis to better understand the implications on propagation characteristics in bubble filled resonant cavities.

Key individuals involved in the work:

D M Farmer is an acoustical oceanographer responsible for project design and analysis

S Vagle is an acoustical oceanographer responsible for implementation of acoustical systems, experimental execution and data analysis

G Deane is an acoustical oceanographer at Scripps who is collaborating in the research including both field studies and acoustic analysis

J Preisig is a researcher from Woods Hole who is collaborating in both field studies and data analysis and interpretation

D Stokes is an interdisciplinary ocean scientist at Scripps who is collaborating in the research including field studies and specialized instrumentation

WORK COMPLETED

1. Planning and design work for shallow water (15m) acoustical communications experiment at the Martha's Vineyard Coastal Observatory (MVCO) set for October and November 2002. Existing high-frequency systems have been modified to explore the different conditions and objectives of the MVCO experiment. The work has included modeling of sensor geometry required to be able to separate wholly refracted paths from surface and bottom reflections associated with bi-directional 33kHz and 100kHz transmissions (Figure 1).

2. Analysis of bubble behavior in a reverberant cavity to determine the reliability of bubble size distribution estimates from acoustical resonators.

3. Analysis of long-term measurements of the bubble generated acoustical barrier in the surf zone.

4. Analysis of bottom generated turbulence in the surf zone in the presence of tides and cross-shore currents.
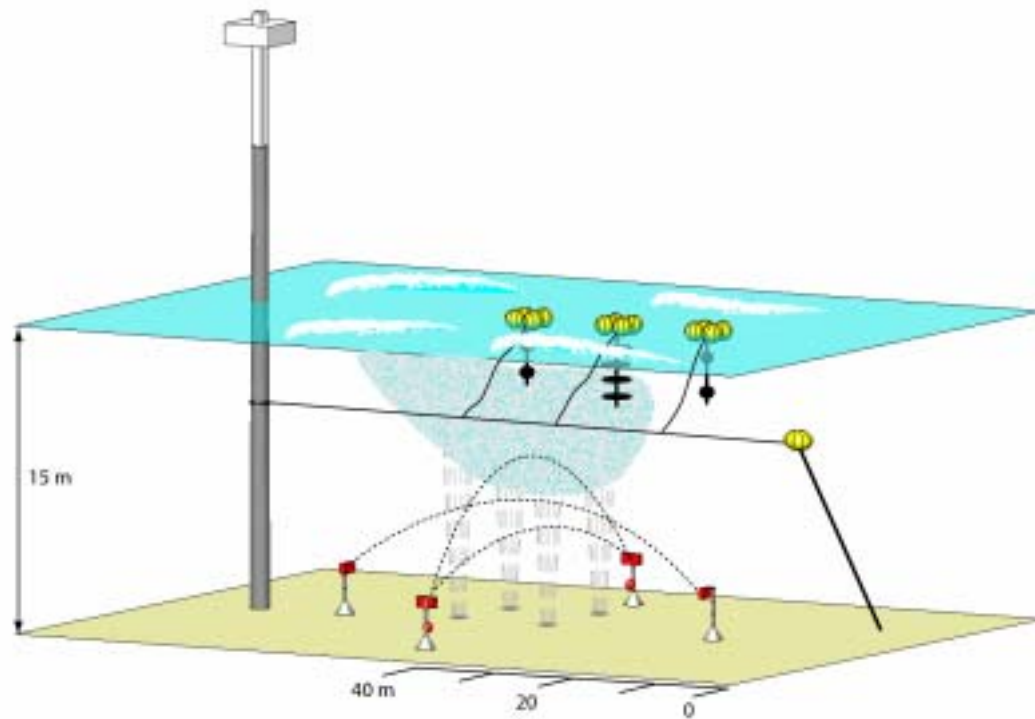
Figure 1. Layout of bubble sensors to be deployed in the Martha's Vineyard Coastal Observatory (MVCO) acoustical communications experiment planned for Fall 2002. The experiment will be carried out in 15m water. The collaboration includes Farmer (GSO), Vagle (IOS), Preisig (WHOI), Deane (SIO) and Stokes (SIO).

RESULTS

Sound propagation in the surf zone have identified the effects of an acoustical barrier formed by large numbers of bubbles being generated when the waves break in this zone (Farmer, Deane, & Vagle, 2001). These bubbles will be advected by long-shore and cross-shore currents, and transformed by dissolution and buoyancy. Wave boundary layer turbulence will also play a role in redistributing the bubbles. Long records of the location of this "bubble wall" have been obtained from 100kHz side-looking sonars pointed shorewards (Figure 2). For the relatively low wave energies experienced during this study there was no significant relationship between wave field and the location of the bubble barrier. The mean depth of the "bubble wall" is approximately 3m with low-frequency variability highly correlated to the tides. High tides saw larger "bubble wall" depths than low tides.
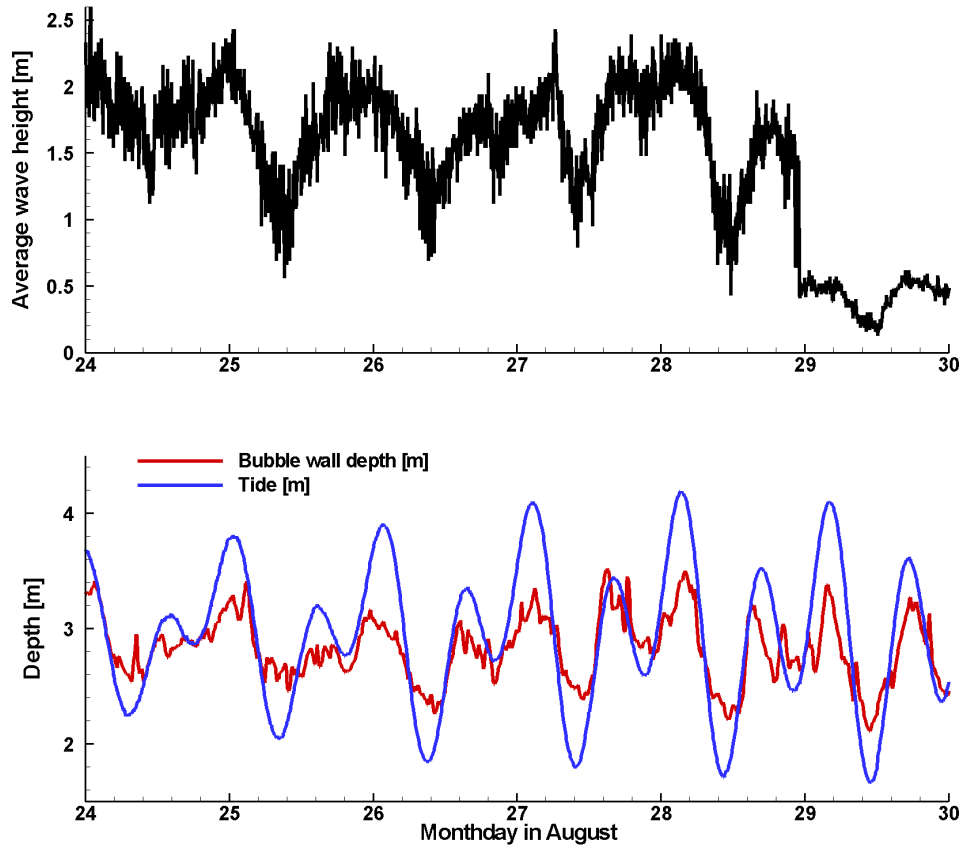
Figure 2. Upper Panel Mean wave-height at the end of Scripps Pier during a six day period. Lower Panel: Associated tidal signal shifted to the mean depth of 3m(blue) and water depth at the location of the "bubble wall" (red).

Building on our earlier work (Vagle, Farmer, & Deane, 2001), we have now added direct measurements of turbulence which may be incorporated in modle calculations of bubble populations in shallow waters adjacent to surf zones. Turbulence levels were measured with a 2MHz coherent doppler sonar 0.5m above the sea floor during a tidal cycle and in the presence of strong long-shore currents, which often indicate the presence of offshore- flowing currents, or rip-currents (Figure 3). Generally, energy dissipation is found to increase as the water level drops; turbulence dissipation also increases by several orders of magnitude, coincident with bursts of increased long-shore flows, the latter thought to be associated with rip-currents. Analysis of independent video recordings also confirm the presence of a rip-current during these periods of enhanced turbulence.
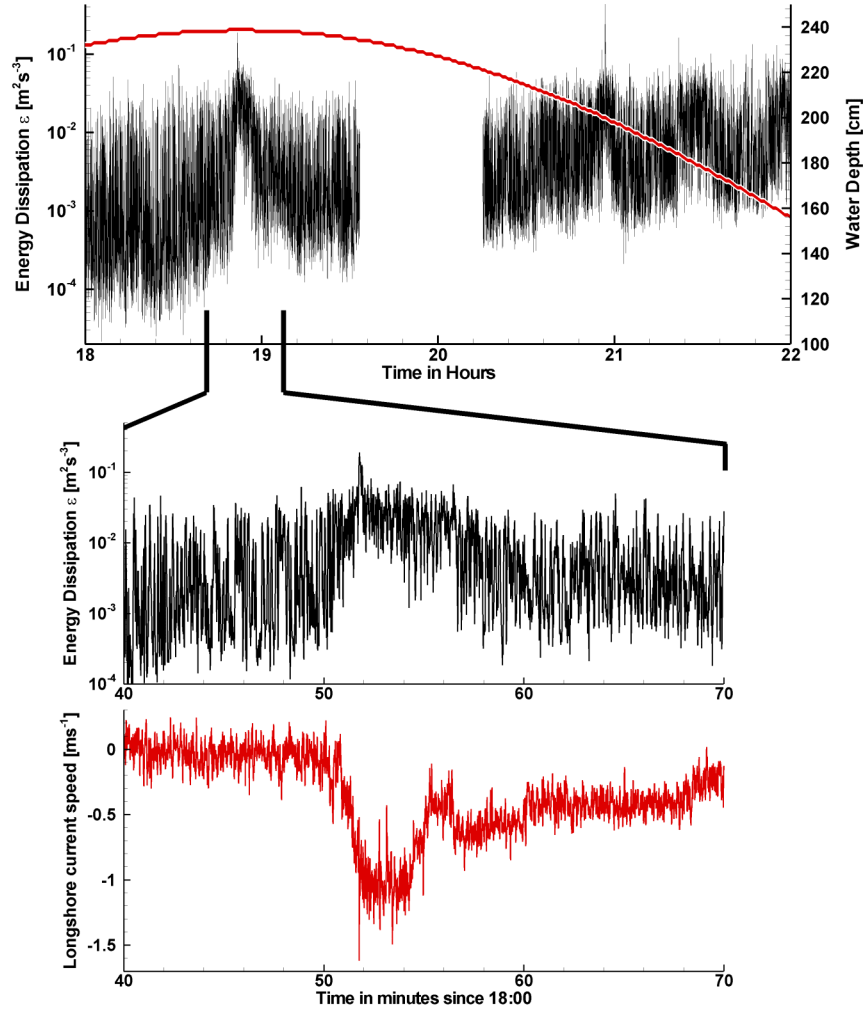
Figure 3. Upper Panel: Energy dissipation ε measured 0.5m from the bottom at 5Hz (black) and water depth at the sensor location (red) for a four hour period. Middle Panel: Expanded thirty minute period of ε showing the increased levels of turbulence between 50 and 60 minutes. Lower Panel: Longshore current speed from range averaged 2MHz Doppler measurements. Presumably these increased long-shore current speeds are associated with offshore-flowing rip-currents.

Since the experiment at Martha's Vineyard has yet to be undertaken, we summarize our continuing effort and results on modeling the performance of bubble sensors using the freely flooding resonator technique (Farmer, Vagle & Booth, 1999). Attention has recently been drawn to limitations of the classical interpretation of bubble behavior in a reverberant cavity. The bubbles contribute to the reverberant field and, in a reciprocal effect, identified by T Leighton (University of Southampton) their response is modified by it. These secondary effects have been shown to be important in the case of a single bubble placed on the axis of a cylinder. In the case of resonator, it can be shown that although large reverberation effects can occur, these are confined to relatively narrow bandwidths. When these narrow bands coincide with the resonator harmonics the resonator measurements may be affected. For the specific geometry we have used to measure ocean bubble populations, reverberation effects turn

out to be small (Farmer, Vagle & Booth, 2002), but a correction technique has been developed for use with resonator data. Alternative geometries can be sensitive to this effect.

IMPACT/APPLICATIONS

Analysis of bubble distributions and turbulence levels in near shore environments are providing important parameters for use in acoustical propagation models. Hydrodynamic considerations of the surface wave field, the bubbles and the turbulence are critical to the development of robust models for these dynamic environments. The reported findings play a significant role in the forthcoming MVCO study and are being used in operational models by Coastal Systems group in Panama City.

RELATED PROJECTS

This work is scientifically linked to the Surf Zone Acoustic Transmission Experiment.

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